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STRENGTH EVALUATION OF CLAYEY SOIL STABILIZED WITH MARBLE SLURRY USED AS SUBGRADE SOIL MATERIAL

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ABSTRACT

This research work focuses on evaluating the effect of marble slurry wastage in stabilizing clayey soil. Normally, Clayey soil expands with the presence of water and shrinks when the water is expelled out of it under load. Therefore, utilizing marble slurry would improve the soil properties, reduce the cost of transportation, minimize and environmental pollution. The work entails treating clayey soil with 0%, 2%, 4%, 6% 8% and 10% replacement of marble slurry. The result shows that the soil is clayey gravel using both AASHTO and USCS with specific gravity 2.74 and a liquid limit of 21%. The MDD was 1.804g/cm^3 at OMC of 16.40% and the soaked CBR is 11.56% all at 10% marble slurry replacement. The optimum marble slurry to be used for stabilizing the clayey soil is 10% for the subgrade construction if it can be properly compacted and covered by an adequate thickness of the pavement.

KEYWORDS: Marble, Strength, Percentage, Replacement & Optimum

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Original Article

1. INTRODUCTION

Nowadays road constructions are faced with several hindrances such as shortage or unavailability of material with desired properties in nearby proposed constructions site, weaker in-situ materials, etc. It is also time-consuming and costlier to transport such construction materials with the desired properties to the proposed construction site. Removing the weaker materials found in place is also problematic. However, most of these explored suitable alternative materials used for stabilizing weak soil are of higher cost and limited in production than the natural soils (Rehana & Kshipra, 2017) Economic and environmental factors need to be considered when selecting a particular admixture for stabilization (Bernardo, *et al.*, 2020). Therefore, utilizing industrial waste products produced in tons as an admixture to improve the soil properties is of great importance. As it will reduce the cost of transportation and avoid deflation of the natural content of the soil (Rehana & Kshipra, 2017; Manohar, *et al.*, 2019; Shraavan & Needhidasan 2018; Serife & Huriye 2016). Another advantage of using these industrial wastes is the issue of waste disposal and environmental pollution would have been reduced Clayey soils or expansive soils are rich in clay minerals (Patil, 2013). It normally causes a devastating problem to general civil engineering constructions, particularly rural road construction (Sreekumar & Mary Rebekah, 2017). Clayey soil exhibits large changes in volume on variations of moisture content under loading conditions (Nikhil, 2014).

The main purpose of soil stabilization is to mainly increase the strength of the weaker soils and at the same time to reduce its permeability and compressibility. These techniques of stabilization can be mechanical, chemical, electrical or thermal (Rehana & Kshipra, 2017). The choice of the stabilization techniques depends upon many factors such as the type of soil to be stabilized, the completion period of the project, location of the project, cost of the project, cost of transporting borrowed materials. Marble originated from the metamorphic rock which possesses

good strength and better resistance to weathering. India has 85-90% of the world's Marble production and has an estimated value of 1200 million tonnes. With the largest deposit of Marble located in Rajasthan. This advantage of Marble natural deposit brings about the concentration of industries that deal with the processing of Marble into different finished products. 25% of the Marble is lost in the form of dust mostly during production which includes dressing, cutting, and polishing (Shashikant, *et al*., 2017).

However, Marble slurry or waste has been disposed of indiscriminately in open places and sewage networks (Shraavan & Needhidasan 2018) Therefore, the wastage powder from these industries is hazardous to human life and the environment in general as a result of its heavy metals constituents. Different materials such as clayey soils used in civil engineering construction fails when subjected to both loading and environmental conditions. To enhance their integrity and stability, stabilizing agents such as lime can be introduced to make it withstand this destructive effect (Fazal, *et al*., 2020). Utilization of such unmanaged wastes in stabilizing weak soil especially in countries like India with a large deposits of clayey soil which cover more than 20% of its landmass is of utmost importance. Therefore, reuse of such wastes as subgrade roadway materials will serve as an alternative solution not only to such a pollution problem, but also to the problem of the economical design of roads (Félix *et al.*, 2018)

It was reported that the California bearing ratio (C.B.R) result of the mixture improved remarkably with the maximum value of 12.5% at 25% addition of marble dust (Ahmed & Fares, 2020). While the compaction result shows that the maximum dry density (MDD) was recorded at 10% replacement with a value of 1.74g/cm^3. According to (Amit, *et al*., 2019) the percentage of stone waste added to the soil to improve it has significantly increased maximum dry density (MDD) with a range of 0.58% to 3.49% while the optimum moisture content decreases as the percentage of waste stone increase. While the work of (Munirwansyah & Pahlevi, 2017) which was aimed at stabilizing expansive soil for subgrade usage using lime. The result from the preliminary tests conducted on the clayey soil revealed that it belongs to group A-7-5 (argillaceous) per AASHTO classification, while using UCSC classification the soil has high plasticity and categorized as fat clay, later the soil was mixed with lime with the percentage variation ranges from 0, 3, 6, 9, to 12. Also, the compaction test result shows that the maximum dry density increased linearly with the highest numerical value as 1.361g/cm^3 at 12% addition of lime.

It was claimed that the usage of marble powder for enhancing the strength of the soil would reduce the level of environmental pollution as well as reduce the cost of conventional building material (Shraavan & Needhidasan 2018). The results of their work revealed that the optimum values of Maximum dry density, CBR and unconfined compression strength obtained were 1.72 gm/cc, 8.474%, and 777.11KN/m^2 respectively at 15% marble powder addition (Yashdeep & Soni, 2017) focused on utilizing the stone slurry waste obtained from marble and cement in stabilizing the clayey soil the samples were subjected to direct shear strength, compaction and California bearing ratio (CBR) tests from the result of the tested specimens it was observed that both additions of stone slurry waste and cement has contributed significantly in improving these properties of soil. Using fly ash, marble dust and river sand to stabilize the black cotton soil to be used as subgrade material per ASTM standard by addition of with different percentages (Chayan & Ravi., 2016). The maximum dry density of black cotton soil increases from 1.53 g/cm^3 to 1.76 g/cm^3 for the final optimum composite whereas the optimum water content of black cotton soil decreases from 22.8% to 19% for the final optimum composite. The soaked and un-soaked CBR value of black cotton soil increases to 189.20% and 99.86% respectively.

Cement is the most effective agent of weak soil stabilization because it contains some compound which helps to strengthen the bonding between the soil particle. However, the exact percentage of cement to be used for stabilizing soil is not constant as a result of the varied properties of soil from one region to another (Habeeb, 2020). California bearing ratio and shear strength increased with an increase of marble powder content material (Dhruv, 2017). As the expansive soil was stabilized with marble powder. The impact of waste marble dust was analyzed in the clayey soil via the addition of marble dust in the soil between 10% to 30%. the liquid limit value decreases from 31.70% to 25%, plastic limit changed from 17.69% to 19.26% and moisture content of clay reduced from 18% to 14.10% and maximum dry density increase from 1.738gm/cc to 1.884gm/cc, CBR Value increases from 2.46% to 6.07% (Hitesh & Gurutej., 2016) Also the marble powder was used in stabilizing the expansive soil by using 5% to 25% of marble. they concluded that an increase in strength of soil in addition to percent of marble powder was noticed (Muthu & Tamilarasan, 2015). The Liquid limit decreases continuously by utilizing all of 5% to 25% addition of marble powder from 70% to 55%, the plastic limit increased with the aid of 25% addition of lime. It was also observed that the Optimum Moisture Content (OMC) of clay accelerated from 18% to 24% and Maximum Dry Density (MDD) increased by up to 10%. In their study evaluated the effects of marble dust on natural soils with three different percentages of 10%, 15% and 20% (Ramoo & Ravi 2018) The optimum results were found when the soil was stabilized with 15% marble dust. The CBR value is increased from 2.36% to 14.86%. and MDD of soil with 20% marble which shows that the CBR results of this soil are good enough for the construction of medium traffic volume roads. It is found that the stabilization of soil by using industrial waste such as marble dust and bagasse ash was successful in improving the poor properties of expansive soil (Ali et., 2014).

This research work will create an inventory that would serve as an information database for both highway and geotechnical engineers on the usefulness of marble slurry in increasing the strength of soils thereby helping to reduce the overall cost of construction since marble is readily available as waste in large quantity and cheap to obtain against other materials used for soil stabilization which are expensive to obtain. This present research is aimed at evaluating the effect of marble slurry on the strength development by clayey soil when used as subgrade materials. The research will be limited to the use of clayey soil of Gangarar town, treated with marble slurry obtainable at the old industrial area of Chittorgarh, Rajasthan India.

2. MATERIAL AND METHOD

2.1 Materials

The disturbed clayey soil sample used for this research was obtained from a borrow pit along the NH 79 Road. The soil sample was taken at the depth of 2.0m below the natural ground level. The soil sample was kept safe, wrapped and packed in a polythene bag to avoid moisture loss. The soil samples were pulverized using mortar and pestle to eliminate the impurities and large particles and subsequently, it was air-dried at room temperature in the Transportations laboratory of the Department of Civil Engineering, Mewar University Rajasthan for about one week to ensure that the soil samples were dried. With regard to this study, the Marble slurry used was obtained in dry powdered form from the marble processing company located at the old industrial area of Chittorgarh, Rajasthan.

2.2 Method

This research work is a laboratory investigation to determine the strength properties of soil properties of compacted clayey soil sample which was treated with 0%, 2%, 4%, 6% 8% and 10% replaced with Marble slurry. The preliminary tests

conducted on the natural clayey soil include natural moisture content, sieve analysis, specific gravity, water absorption, atterberg limit. Other tests were conducted on the clayey soil treated with the proportion of marble slurry cover compaction characteristics determination and California bearing ratio (CBR). All tests conducted were per the Indian Standard specification.

3. ANALYSIS AND DISCUSSION OF RESULT

3.1Preliminary Test Result

Table 1: Result from Preliminary **T**est

S/No	Parameter	Value
1	Natural Moisture Content	8.10%
2	Specific Gravity	2.6
3	Water Absorption	2.74%

From Table 1.0 above it can be seen that the moisture content was calculated and found to be approximately 8%. The average natural moisture content is low because the soil sample was obtained during the dry season. Ideally, the specific gravity of a soil with higher strength should have a value of 2.50 up to 2.85 per provision of (IS: 2720 Part-3 – 1980). This implies that the higher the value of specific gravity the higher the expected strength of the materials which can be used as construction materials. And in this case, the value of specific gravity obtain from the analysis is 2.60 which was presented in the above table. It shows a quality material for construction purposes, but this can be improved by using an admixture to stabilize it which is the main objective of this research work. The maximum amount of water absorption for a good quality material used for construction should not exceed 3% and for the case of this research work the average water absorption by mass obtained was 2.74% which is within the recommended value prescribed in Standard (IS: 2386 Part 3 – 1963)

3.2 Sieve Analysis

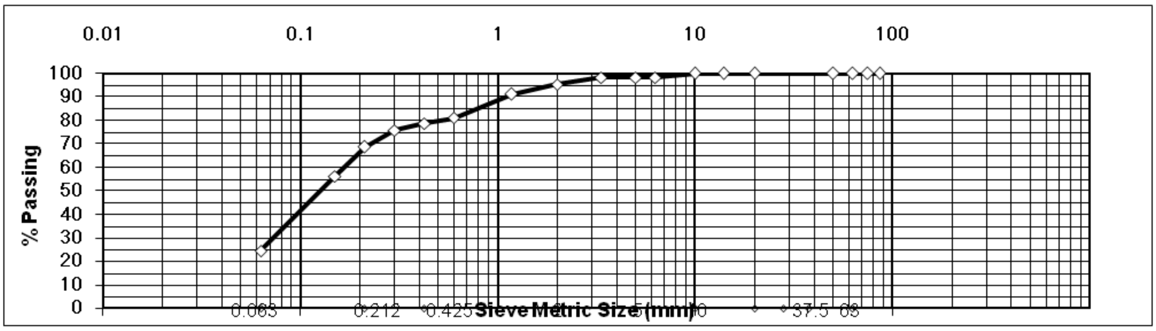


Figure 1: Particle Sizes Distribution

Soil Classification

Since the amount of soil particles passing sieve No. 200 (0.075mm) is lee than 35% i.e. only 25% of the particles passed through the No.200 sieve (0.075mm) as represented in table 4.2 and figure 4.2. then the soil can be classified as either in group A-1 or group A-2. The amount of soil that passes through No. 40 sieve size is less than 10%, therefore the soil can be classified as A-2-5 that is clayey gravel sand. Therefore, it can be regarded as poor material for subgrade construction if it can be properly compacted and covered by an adequate thickness of the pavement. from the recommendation made by (AASHTO, 2007). The soil classification is based on (ASTM 408, 2002). Since only 4.20% of the particles passed through

the No.200 sieve (0.075mm) and also have more than 50% soil passed through No. 4 sieve (4.75mm) then the soil can be categories as Sand which can either be well or poorly graded depending on the two shape parameters i.e. coefficient of curvature and uniformity coefficient as seen below. Based on the unified soil classification system (UCSC) the soil sample is well-graded sands, with little or no fines (silts) with a symbol of SW as the value of Coefficient of curvature (Cc) is 1.13 which lies between 1 and 3. also the value of Coefficient of Uniformity (Cu) is 12.50 which is more than 6.

3.3Atterberg Limits

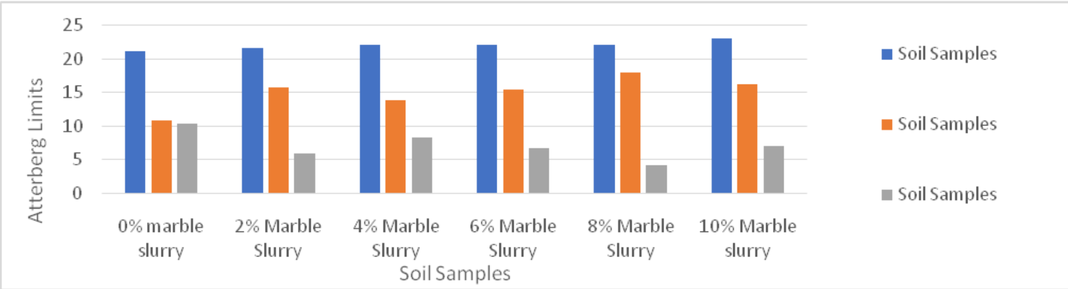
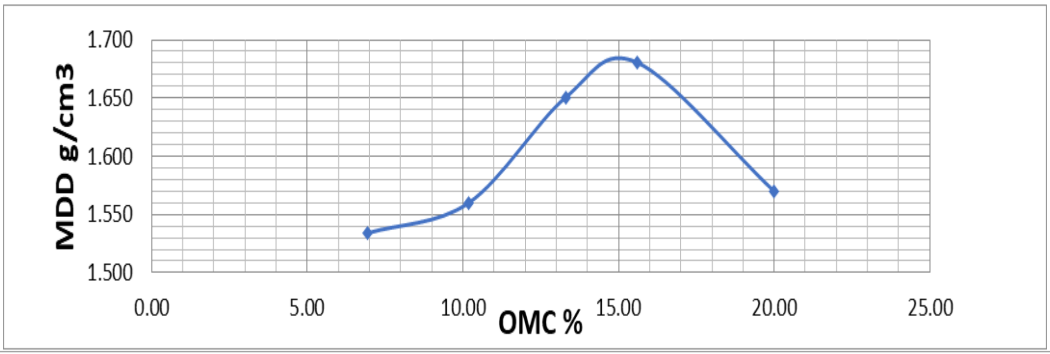


Figure 2: Atterberg Limits.

From the figure above it can be seen that the addition marble slurry has a considerable effect in increasing the constituency of the soil particle. The plasticity index is indirectly proportional to the clay content. This explains why the tropical lateritic soils with lower clay content are better construction materials than the more plastic clays with high clay content. The Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of the natural soil samples are 21.00, 10.70 and 10.30% respectively. This shows that the soil sample is of low plasticity. Therefore, this soil may have a very high shear strength value as its plasticity index is very less, also the silt content in the soil is less.

3.4 Compaction Characteristic



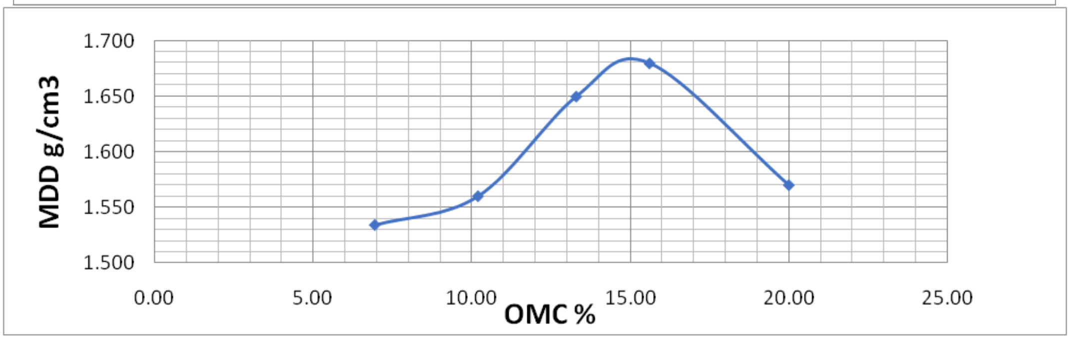


Figure 3; Compaction Characteristics at 0% Replacement.
Figure 4: Compaction Characteristics at 2% Replacement.

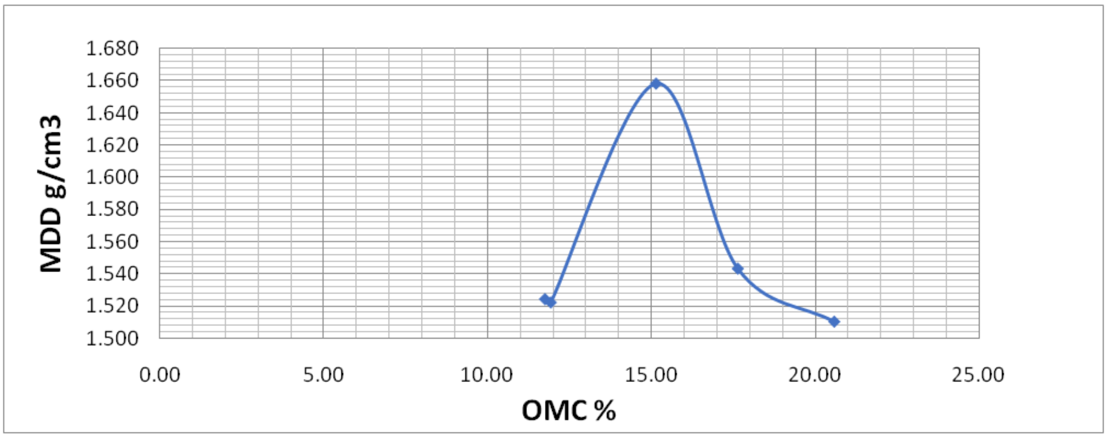


Figure 5: Compaction Characteristics at 4% Replacement.

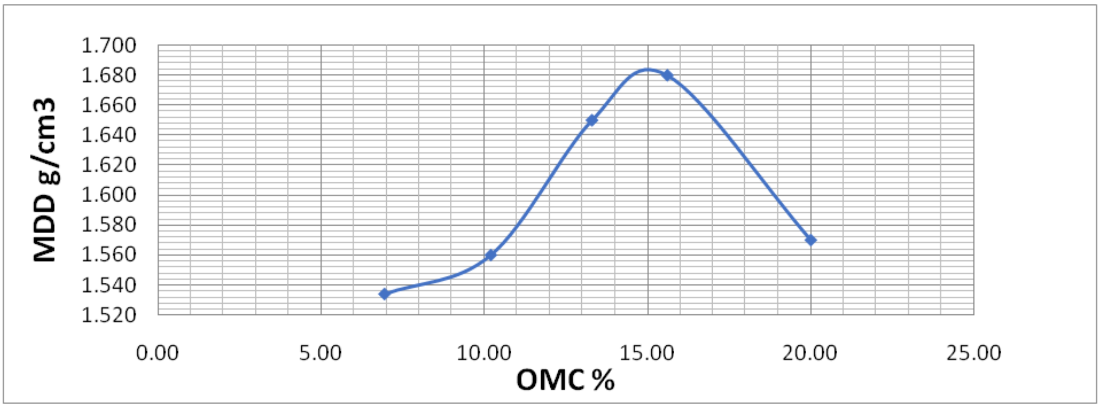


Figure 6: Compaction Characteristics at 6% Replacement.

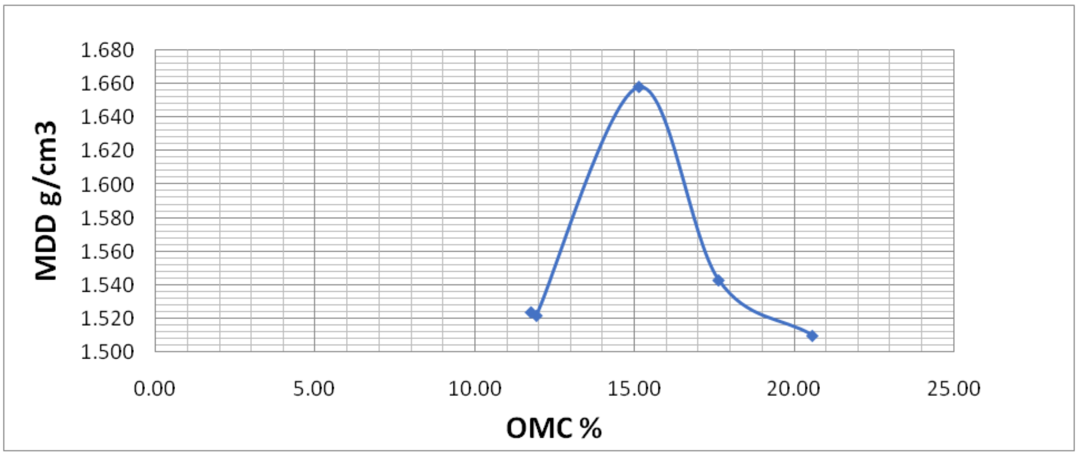


Figure 7: Compaction Characteristics at 8% Replacement.

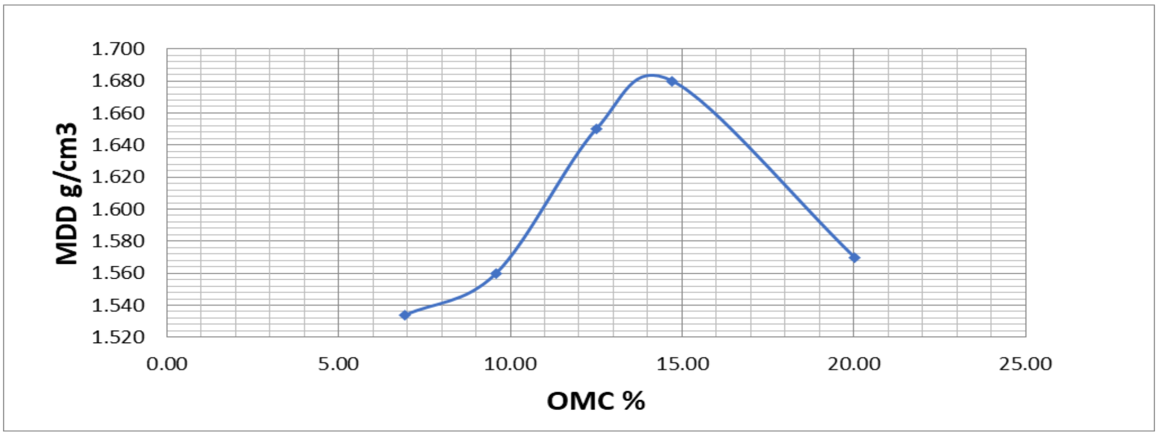


Figure 8: Compaction Characteristics at 10% Replacement.

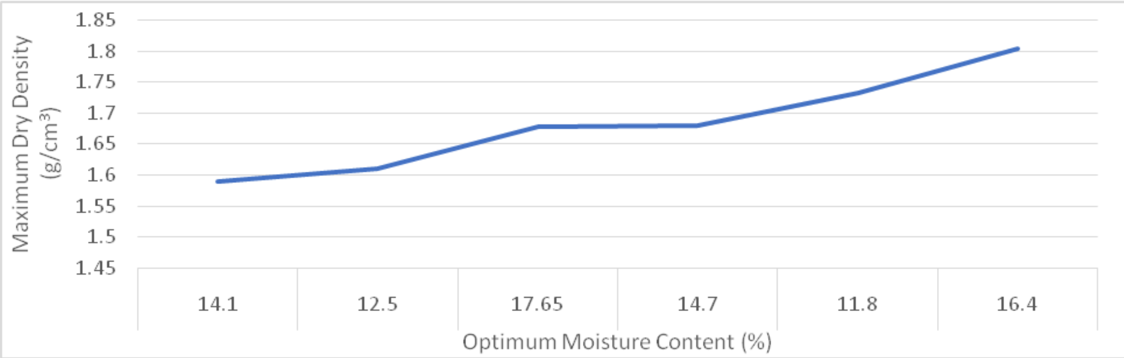


Figure 9: Maximum Dry Densities and Corresponding Moisture Contents.

These parameters of compaction characteristic are very important used in checking the suitability or otherwise of the stabilized soil to be used for road works especially for compaction to reduce any expected settlement. The compaction characteristics was presented in figure 9 above in terms of dry densities and moisture contents. it can be observed that the maximum dry densities increase with the increase in the percentage of marble slurry from 0%, 2%, 4%, 6%, 8% and 10% replacement with values of 1.590, 1.610, 1.679, 1.680, 1.732 and 1.804g/cm^3 respectively. While the optimum moisture contents decrease with the increase in the percentage of the moisture content. This can evidently compare from the research of (Ramoo & Ravi, 2018) and when compared with the I.S recommendation the ranges of values obtained are with the permissible values for the subgrade design. Therefore, the marble slurry can be used as an alternate material to stabilize the clayey soil or used as subgrade. This is because the strength of each compacted layer entirely depends on the maximum density of the soil which is normally achieved through compaction.

3.5 California Bearing Ratio (CBR)

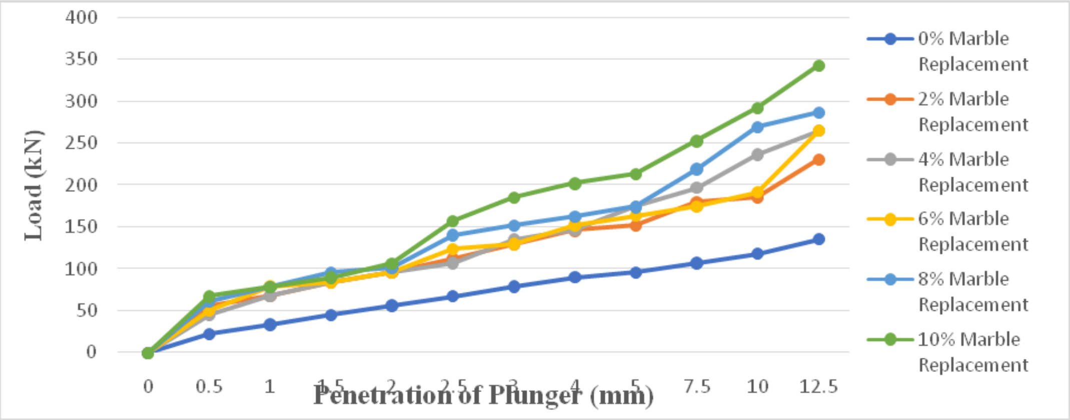


Figure 10: California Bearing Ratio (CBR) Result.

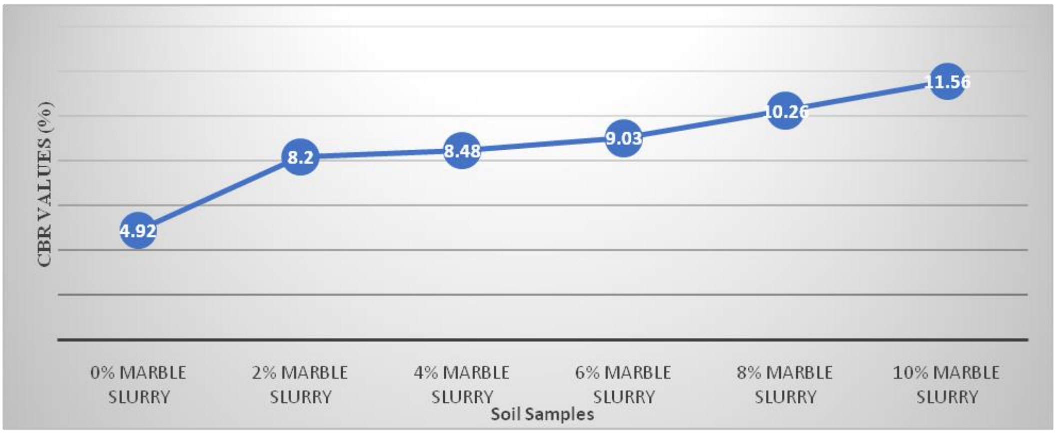


Figure11: Selected California Bearing Ratio (CBR) Values for Design.

The value of CBR increases as the value of the marble slurry used increases from 0, 2, 4, 6, 8 and 10%. with their respective increment of CBR values of 4.92, 8.20, 8.48, 9.03, 10.26 and 11.56% as per Indian Road Congress (IRC) recommendation and Indian Standards (IS: 2720 Part 16 – 1987). The minimum value of C.B.R. required for a subgrade should be 8%. Therefore, the optimum value of Marble slurry that can be used for stabilizing the clayey soil is 10% with a corresponding CBR value of 11.56%.

4. CONCLUSIONS

Based on the result obtained from the analysis conducted on checking the suitability of the marble slurry for stabilizing and/or improving the performance of the clayey soil to be used as subgrade material in road construction. The following conclusions were drawn:

- The preliminary tests conducted on the natural clayey soil revealed that the sieve analysis (Grain Size Distribution) resulted in a poorly-graded soil and it belongs to class A-2-5 i.e. clayey gravel sand based on classification (AASHTO, 2007) and its corresponding class in (ASTM 408, 2002). Classification is clean sand with no or little fine particles with a symbol of SW. While the natural moisture content of the soil is 8% which shows a soil with a very low amount of moisture. The result of the specific gravity shows that the value obtained

is within the range of the recommended value prescribed by the (IS: 2386 (Part 3) – 1963) with a value of 2.71. and also, the amount of water absorbed by the soil is 2.74% which is also less than the maximum value of the water absorption of 3%.

- The result of the consistency test shows a soil with a low plasticity index having respective values of Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) as 21.00, 10.70 and 10.30%. with a value of Liquid Limit (LL) less than 30%, this shows a soil with expected considerable shear strength value. Also, the atterberg limit at different amounts of the marble slurry is also less than 30%. Which confirmed the expected strength properties of the soil.
- The result of light compaction revealed that the maximum dry densities increase with the increase in the percentage of marble slurry from 0%, 2%, 4%, 6%, 8% and 10% replacement with values of 1.590, 1.610, 1.679, 1.680, 1.732 and 1.804g/cm^3 respectively, while the optimum moisture content decrease with the increase in the percentage of the moisture content.
- The California Bearing Ratio (CBR) values from the test conducted increases proportionally as the amount of the marble slurry increases. i.e. marble slurry used from 0, 2, 4, 6, 8 and 10%. with their respective increment of CBR 4.92, 8.20, 8.48, 9.03, 10.26 and 11.56%. and the minimum allowable CBR value for the subgrade material is 8%. Therefore, the optimum value is 11.56%. with a 10% marble slurry replacement.

From all the tests conducted to check the suitability of the marble slurry as a material that can be used for stabilizing or improving the quality of the clayey soil to be as subgrade material for road construction. Tt was found that the marble slurry can be used for both purposes as all these parameters checked increased proportionally with the increase with the amount of the marble percentage. Therefore, from this research, it can be concluded that the mixture of 90% soil and 10% marble slurry can be regarded as good material for subgrade construction if it can be properly compacted and covered by an adequate thickness of pavement. as [24] recommended from their work.

5. RECOMMENDATIONS

The following recommendation can be drawn from this research work

- The variation of properties of clayed soil with a higher percentage of marble slurry should be checked to maximize the level of utilizing the amount of waste product of marble slurry and minimize the depletion of natural reserve soil material.
- Other strength properties such as unconfined compressive strength and shear strength of the soil should be checked at a different higher percentage of the marble slurry replacement.
- The consolidation test should be performed at a different percentage of the marble replacement to check the settlement level of the soil when subjected to vertical static loading.
- The suitability of the used of marble slurry in stabilizing clayey soil to be used as a material for other sub-layers apart from the subgrade should be checked.

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